WAVEGUIDED DISPLAY SYSTEMS

[0001] This application claims the benefit of provisional patent application No. 62/731,309, filed Sep. 14, 2018, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

[0002] This relates generally to electronic devices and, more particularly, to electronic devices with displays.

[0003] Electronic devices with displays may be used to display content for a user. If care is not taken, the components used in displaying content for a user in an electronic device may be unsightly and bulky and may not exhibit desired levels of optical performance.

SUMMARY

[0004] An electronic device may have a display that emits image light, a waveguide, and an input coupler that couples the image light into the waveguide. Beam splitter structures may be embedded within the waveguide. The beam splitter structures may reflect the image light multiple times and may serve to generate replicated beams of light (e.g., expanded output light) that are coupled out of the waveguide by an output coupler. The beam splitter structures may replicate the beams across two dimensions (e.g., across the lateral area of the waveguide). In this way, an eye box may be provided with uniform-intensity light from the display across its area and for a wide field of view.

[0005] The beam splitter structures may include stacked beam splitter layers. For example, first and second partially reflective beam splitter layers may be embedded in the waveguide. The second beam splitter layer may partially or completely overlap the first beam splitter layer. Additional beam splitter layers may be stacked over the first and second beam splitter layers or laterally displaced with respect to the first and/or second beam splitter layers.

[0006] In another suitable arrangement, the beam splitter structures may be formed from first, second, and third transparent substrate layers of the waveguide. In this scenario, each transparent substrate layer may have a respective index of refraction so that interfaces between the substrate layers generate reflected light that is coupled out of the waveguide.

[0007] In yet another suitable arrangement, the beam splitter structures may include a thick volume hologram interposed between two transparent substrate layers. In this scenario, the thick volume hologram layer may partially reflect the image light at multiple depths relative to one of the substrate layers as the image light traverses the thickness of the thick volume hologram layer. Combinations of these arrangements may be used to form the beam splitter structures. If desired, the reflectivity of the beam splitter structures may vary discretely or continuously across the lateral area of the waveguide.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a schematic diagram of an illustrative head-mounted device in accordance with an embodiment.

[0009] FIG. **2** is a diagram of an illustrative head-mounted device for a single eye in accordance with an embodiment.

[0010] FIG. **3** is a top view of an illustrative optical system and associated display system for a head-mounted device in accordance with an embodiment.

[0011] FIG. **4** is a top view of an illustrative optical system having a waveguide without beam splitter structures in accordance with an embodiment.

[0012] FIG. **5** is a top view of an illustrative optical system having beam splitter structures embedded within a waveguide for filling an eye box with light in accordance with an embodiment.

[0013] FIG. **6** is a top view of illustrative beam splitter structures having a single beam splitter layer embedded within a waveguide in accordance with an embodiment.

[0014] FIG. **7** is a top view of illustrative beam splitter structures having multiple stacked beam splitter layers embedded within a waveguide in accordance with an embodiment.

[0015] FIG. **8** is a top view of illustrative beam splitter structures having multiple stacked and laterally-offset beam splitter layers embedded within a waveguide in accordance with an embodiment.

[0016] FIG. **9** is a top view of illustrative beam splitter structures having multiple partially-overlapping beam splitter layers embedded within a waveguide in accordance with an embodiment.

[0017] FIG. **10** is a top view of illustrative beam splitter structures having multiple layers with different indices of refraction in accordance with an embodiment.

[0018] FIG. **11** is a top view of illustrative beam splitter structures having a thick volume hologram embedded within a waveguide in accordance with an embodiment.

[0019] FIG. **12** is a top view of illustrative beam splitter structures having a single beam splitter layer with regions having different reflection and transmission coefficients in accordance with an embodiment.

[0020] FIG. **13** is a top view of illustrative beam splitter structures having a single beam splitter layer with continuously varying transmission and reflection coefficients along their length in accordance with an embodiment.

[0021] FIG. **14** is a perspective view of a waveguide of the type shown in FIG. **4** in accordance with an embodiment.

[0022] FIG. **15** is a perspective view showing how a waveguide of the types shown in FIGS. **5-14** may fill an eye box with light across two dimensions in accordance with an embodiment.

DETAILED DESCRIPTION

[0023] Electronic devices such as head-mounted devices and other devices may be used for augmented reality and virtual reality systems. These devices may include portable consumer electronics (e.g., portable electronic devices such as tablet computers, cellular telephones, glasses, other wearable equipment, etc.), head-up displays in cockpits, vehicles, etc., and display-based equipment (televisions, projectors, etc.). Devices such as these may include displays and other optical components. Device configurations in which virtual reality and/or augmented reality content is provided to a user with a head-mounted display device are described herein as an example. This is, however, merely illustrative. Any suitable equipment may be used in providing a user with virtual reality and/or augmented reality content.

[0024] A head-mounted device such as a pair of augmented reality glasses that is worn on the head of a user may be used to provide a user with computer-generated content